1. INTRODUCTION

1.1 Background

With the development of economic around this world, clean water resources are greatly utilized. Desalination of seawater by forward osmosis technology becomes one of the important researches for clean water supply. Osmosis defined as the transfer of water particles through a selectively permeable membrane driven by a concentration gradient (McCutcheon et al., 2005). During the last four decades, many researches about FO osmosis have been studied but mainly focused on achieving high water flux by choosing the right draw solution. The draw solutions that have been chosen are glucose, sulphur dioxide (SO_2) and aluminium sulphate ($Al_2(SO_4)_3$) (Batchelder, 1965; Frank, 1972; Kravath, 1975; Stache, 1989). After this, a two stage FO process was patented by using draw solutions potassium nitrate (KNO_3) and sulphur dioxide (SO_2) in first stage and second stage respectively (McGinnis, 2002). However, performance data were either limited or not reported. Recently, based on the reports from various researches and patents, ammonium bicarbonate was introduced as new novel draw solution (McCutcheon et al., 2005) and new developed CTA membrane was used as the FO membrane. However ammonium bicarbonate was found that not stable in high temperature. In addition, there is a lack of mechanistic explanation on the effects of various factors on the performance of the FO process. To date, only two studies were reported on the impact of one of the affecting factors: membrane structure. Loeb et al. (1997) conducted a static osmosis study and discussed about the effects of membrane structure on osmosis using RO cellulose acetate asymmetric membrane. McCutcheon (2005) briefly mentioned that "internal concentration polarization" would adversely affect the performance of the cellulose ester FO membrane in the dynamic FO process.

1.2 Motivation

Clean water play an important role in our daily life, we use water in drinking, cooking, bathing, industries and agriculture. About 97% of water in our earth covered by seawater therefore seawater considered the most potential clean water resources. However, desalination of seawater was considered as challenged process because of high energy and cost consumed.

Therefore, the introduced of forward osmosis (FO) as one of the technologies in desalination of seawater which is more valuable with low operating cost (McChutcheon et al., 2006). For this research, forward osmosis (FO) was chosen instead of reverse osmosis (RO) because RO is pressure-driven membrane separation processes which required more energy. In forward osmosis, selected a suitable draw solution and an optimum semi-permeable membranes are the crucial things to obtain a good result of FO system. The current available membrane which is commercialised is cellulose triacetate (CTA) membrane developed by HTI (Hydration Technologies Albany, OR). A suitable draw solution need to fulfil the requirements which are high water flux, low reverse salt diffusion and easy recovery of the diluted draw solution (Chekli et al., 2012; Ge et al.,2013).

In addition, nowadays there are a lot of studies that related to desalination of seawater by using reverse osmosis. Besides that, reverse osmosis is the technologies established in large scale and commercially around the world. However, researches for forward osmosis in desalination of seawater are scarce. In order to produce high quality of clean water, the research on forward osmosis for seawater should be investigated. This research also important to reduce the problem of water crisis by using a less energy and cost consumed technology.

1.3 Problem statement

Reverse osmosis (RO) is the technology which is commonly used in water treatment but cannot achieved high recovery of water flux due to hydraulic pressure limitation of the pumps and membrane fouling. Besides that, forward osmosis (FO) is a process that is more valuable but the challenged of this process is lack of optimised membrane and draw solution. Moreover, forward osmosis also met the problem which is the reverse salt diffusion which can influence its performance.

1.4 Objective

The objective of this research is to perform desalination of seawater by using cellulose triacetate (CTA) FO membrane with sodium sulphate as draw solution.

1.5 Scope of research

To achieve the objective in this research, three main scopes of research had been identified. The following are the scopes of this research:

1. First, the performance of CTA membrane was tested in terms of pure water permeability. This is done by determine the water flux by using different pH of draw solution (pH 3,7 and 9) and different concentration of draw solution (1.0M, 1.25M, 1.50M, 1,75M and 2.0M).
2. The second scope of this research is to study the effect of orientation of CTA membrane. There are two modes of membrane orientation in FO which are the porous layer facing the feed solution and the dense layer facing the draw solution and vice versa. This result will help in knowing the best orientation of membrane in desalination of seawater.
3. Finally the last scope is to study the effect of different of pH and concentration for the draw solution sodium sulphate on reverse salt flux (RSF).

1.6 Organisation of this thesis

The structure of the reminder of the thesis is outlined as follow:

Chapter 2 introduces the membrane technology used in water treatment and the fundamental principles of osmosis and forward osmosis (FO). Besides that, this chapter discusses on the advantages of using FO method and its applications. The differences between FO and the current most popular membrane process RO are also compared. In addition, this chapter provides a description on the different method of membrane technologies currently used in this era. Furthermore, this chapter discusses on the common membrane used for forward osmosis process known as cellulose triacetate (CTA) membrane. The selection of Na_2SO_4 draw solution and its properties that could influence the FO performance is also discussed on this chapter. Lastly, this chapter also looks into the current challenges of FO that can gravely affect the efficiency of the process which are concentration polarization, membrane fouling and reverse salt diffusion.

Chapter 3 provides description on the chemicals used and methodology of this research which includes the procedures to characterize CTA FO membrane in terms of physical